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CONDITION MODELS FOR WINTERING NORTHERN PINTAILS IN THE SOUTHERN HIGH PLAINS

Loren M. Smith[1], Douglas G. Sheeley[2], and David B. Wester[1]

ABSTRACT—Three condition models for wintering Northern Pintails (*Anas acuta*) were tested for their ability to predict fat mass, logarithm of fat mass, or a condition index (CI) incorporating fat mass. Equations generated to predict fat mass and the logarithm of fat mass accounted for more than 69% of the variation in these dependent variables. Log transformations of body mass, wing length, and total length explained at least 60% of the variation in CI. All models performed better on an independent data set. Mean prediction error was minimal (≤8% of measured variables) and negative for all models. Regression models apply to live and dead pintails and thus represent tools that have utility in a wide variety of studies on pintail condition.

Key words: Northern Pintails, Anas acuta, *body condition, predictive models, Texas, waterfowl.*

Biologists have used various indices for assessing waterfowl nutritional status. Initially, only body mass was used (Hanson 1962, Folk et al. 1966, Street 1975, Flickinger and Bolen 1979), but later structural variables were incorporated to adjust for individual size differences (Owen and Cook 1977, Bailey 1979, Wishart 1979). Ringelman and Szymczak (1985) and Johnson et al. (1985) reviewed avian condition indices and noted the value of an accurate index of lipids in migratory bird management. These studies noted that scaling morphological variables with body mass provided useful indices to avian body condition.

Northern Pintails (*Anas acuta*) are one of the most widespread waterfowl species in North America (Bellrose 1980), but recently their populations have declined, making them a species of special concern (Smith et al. 1991). Our objectives were to provide an equation to predict total carcass fat (body condition) of Northern Pintails and to test that index on an independent data set. The anatomical variables tested are suitable for field studies.

STUDY AREA

The study was conducted in the Southern High Plains (SHP) of Texas, an 82,880-km^2 area that is one of the most intensively cultivated regions in the Western Hemisphere (Bolen et al. 1989). Twenty thousand playas are present in the SHP providing winter habitat for waterfowl (Haukos and Smith 1992). At least one-third (≥300,000) of the Northern Pintails wintering in the Central Flyway winter on the SHP (Bellrose 1980).

METHODS

Northern Pintails were collected using decoys and by jump-shooting on playas and associated tailwater pits in the SHP from October through March of 1984–85 and 1985–86. Tarsal length (measured from the junction of the tibiotarsus and tarsometatarsus to the point of articulation between the tarsometatarsus and middle toe, 0.01 mm), flattened wing chord (measured from the insertion of the alula to the tip of the tenth primary, 0.1 cm), and total body length (measured from the tip of the bill to the end of the pygostyle, thus avoiding complications due to tail feather growth, 0.1 cm) were recorded for each bird. During 1985–86 an additional wing measurement was recorded from the insertion of the alula to the tip of the ninth primary because the ninth primary may be slightly longer than the tenth. Birds were plucked and frozen.

Ingesta and intestinal contents were removed in the laboratory. Birds then were

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[1] Department of Range and Wildlife Management, Texas Tech University, Lubbock, Texas 79409
[2] Box 464, Eldora, Iowa 50627

TABLE 1. Variables used in predictive models of body condition for Northern Pintails (*Anas acuta*) on the Southern High Plains, Texas.

Variable	Adult males (n = 140) $\bar{x}$	SE	Adult females (n = 69) $\bar{x}$	SE	Juvenile males (n = 58) $\bar{x}$	SE	Juvenile females (n = 49) $\bar{x}$	SE
Mass (g)	963.93	10.94	835.07	12.60	911.97	16.41	786.68	14.90
Tarsal length (mm)	41.15	0.17	38.68	0.23	41.13	0.25	38.90	0.30
Wing length (cm)	26.58	0.06	24.69	0.08	25.92	0.10	24.23	0.09
Total length (cm)	49.72	0.12	43.37	0.14	49.53	0.22	43.14	0.19
Lipid mass (g)	171.57	6.27	173.20	8.33	147.93	11.07	148.21	9.56

reweighed (nearest 0.01 g) to determine a net carcass mass and refrozen (Table 1). Frozen birds were sectioned with a meat saw and passed twice through a meat grinder. The homogenate was dried to a constant mass in either a forced-air oven (60 C) or freeze dryer. Dried pintails were reground to insure a uniform mixture. Lipid was extracted from 10–15 g samples using petroleum ether solvent in a Soxhlet apparatus (36–48 hrs). Fat-free dry mass (FFDM) was calculated by subtracting water and lipid from total carcass mass (body mass minus feathers and ingesta). Total carcass mass minus water mass yielded dry mass (DM).

Three models were evaluated to predict (1) fat mass, (2) a condition index (CI) incorporating fat mass, and (3) the logarithm of fat mass of wintering Northern Pintails. First, pintails were sorted by sex (age was not significant; multiple regression, $P > .05$). A predictive model for fat was generated for each sex using total body length (TOTAL), wing length (WING), tarsal length (TARSAL), and body mass (MASS) as explanatory variables.

In model 1, regression coefficients of explanatory variables between sexes were not different ($P > .05$). A predictive equation applicable to both sexes was therefore constructed which included a dummy variable for sex (DSEX) as well as structural variables.

The second model was constructed following Johnson et al. (1985); a Lipid Index was defined:

$$\text{Lipid Index} = \text{Fat} / \text{FFDM}.$$

Fat-free dry mass is included to correct for size differences between individuals. Lipid Index was transformed to:

$$\text{CI} = \log(\text{Lipid Index} + 1)$$

because the structural measurements are allometric and because logarithms can be used to linearize ratios (Johnson et al. 1985). The constant 1 was added to smooth the function. CI can be simplified to:

$$\text{CI} = \log(\text{DM}/\text{FFDM})$$

because

$$\text{DM} = \text{Fat} + \text{FFDM}.$$

Log FFDM was modeled as a function of the logarithms of structural variables (LTOTAL, LWING, and LTARSAL) and log DM as a function of these plus the logarithm of body mass (LMASS) (Johnson et al. 1985). Unlike Mallards (*Anas platyrhynchos*; Ringelman and Szymczak 1985) and Canada Geese (*Branta canadensis*; Raveling 1979), water content of wintering Northern Pintails fluctuated widely (Smith and Sheeley 1993). Therefore, we did not test fat-free mass as an index to structural size (Ringelman and Szymczak 1985).

Johnson et al. (1985) used logarithms of structural variables to model logarithms of carcass fat mass (log fat). A separate equation was estimated for each age/sex group (model 3) using dummy variables for age (DAGE) and sex (DSEX) because regression coefficients for explanatory variables differed ($P < .05$) among these four groups.

Predictive equations were validated on a data set of 40 randomly selected pintails not included in the generation of models. Percentages of each age/sex class of pintails in the independent sample were consistent with their occurrence in the sample collection.

Prediction error (PE) was calculated as an additional test of model performance. PE is defined as:

$$\text{PE} = \text{Measured Y} - \text{Predicted Y}$$

where Y is the dependent variable. Mean PE is an average value for all members of the validation data set. Finally, predicted fat, CI, and log fat were correlated with Lipid Index in the validation data.

TABLE 2. Regression equations and associated statistics for predicting carcass fat (model 1) content (g) in Northern Pintails (*Anas acuta*) collected on the Southern High Plains of Texas, October–March 1984–86.

			Explanatory variables				
Equation	R^2		Intercept	MASS	WING	TOTAL	DSEX
1.1	.779	Parameter estimate	191.854	0.560	−13.386	−4.136	—
(Male; $n = 198$)		SE	—	0.022	3.894	1.901	—
		Variance inflation factor	—	1.181	1.231	1.221	—
		Partial R^2	—	0.741	0.013	0.005	—
1.2	.711	Parameter estimate	145.570	0.570	−9.516	−4.953	—
(Female; $n = 118$)		SE	—	0.035	5.561	2.994	—
		Variance inflation factor	—	1.125	1.212	1.174	—
		Partial R^2	—	0.691	0.007	0.007[a]	—
1.3	.757	Parameter estimate	190.494	0.563	−12.068	−4.409	−22.513
(Combined; $n = 316$)		SE	—	0.018	3.178	1.600	10.536
		Variance inflation factor	—	1.492	3.164	6.842	5.987
		Partial R^2	—	0.726	0.011	0.006	0.004

[a] Not significant ($P > .05$)

TABLE 3. Regression equations and associated statistics for predicting Condition Index (model 2) in Northern Pintails (*Anas acuta*) collected on the Southern High Plains of Texas, October–March 1984–86.

			Explanatory variables				
Equation	R^2		Intercept	LMASS	LWING	LTOTAL	DSEX
2.1	.673	Parameter estimate	−0.816	1.371	−1.025	−0.909	—
(Male; $n = 198$)		SE	—	0.069	0.343	0.312	—
		Variance inflation factor	—	1.190	1.233	1.229	—
		Partial R^2	—	0.656	0.015	0.014	—
2.2	.599	Parameter estimate	−0.725	1.316	−1.179	−0.710	—
(Female; $n = 118$)		SE	—	0.101	0.512	0.486	—
		Variance inflation factor	—	1.123	1.206	1.176	—
		Partial R^2	—	0.595	0.019	0.008	—
2.3	.657	Parameter estimate	−0.761	1.350	−1.080	−0.834	−0.041
(Combined; $n = 316$)		SE	—	0.057	0.286	0.264	0.016
		Variance inflation factor	—	1.496	3.207	7.035	6.141
		Partial R^2	—	0.610	0.016	0.011	0.007

Stepwise multiple regression (maximum R^2 improvement technique) was used to generate and test all models (SAS Institute, Inc. 1985). Variables were eliminated that did not contribute significantly ($P < .05$) to a model. Partial R^2 values were calculated for each variable in a model. A sum of squares (Type II) for each model variable was divided by the total sum of squares in the model. A partial R^2 value for a given variable represents the unique contribution of that variable when all other variables are already present in the model. Partial R^2 values are not additive, and, therefore, their sum will not equal the total model R^2. Differences in variation accounted for by ninth versus tenth primary length were evaluated using the R^2 procedure (SAS Institute, Inc. 1985).

RESULTS

In model 1 (Table 2) body mass explained a major portion of variation in carcass fat content in males (equation 1.1) and females (equation 1.2). Total length did not account for a significant ($P > .05$) portion of variation in fat content for females as it did males. Based on low variance inflation factors (VIF), regression coefficient estimates for each sex were stable. When sexes were combined through use of a dummy variable (equation 1.3), the VIF for TOTAL and DSEX were relatively high; this is largely attributable to the high correlation between length and sex of bird (point biserial correlation coefficient equal to 0.91).

LTOTAL, LWING, and LTARSAL explained variation in log FFDM. For modeling,

TABLE 4. Regression equations and associated statistics for predicting log carcass fat (model 3) in Northern Pintails (*Anas acuta*) collected on the Southern High Plains of Texas, October–March 1984–86.

			Explanatory variables		
Equation	R^2		Intercept	LMASS	LWING
3.1	.727	Parameter estimate	−3.410	3.412	−3.209
(Adult male; $n = 140$)		SE	—	0.182	0.993
		Variance inflation factor	—	1.156	1.156
		Partial R^2	—	0.697	0.021
3.2	.693	Parameter estimate	−1.611	3.687	−4.998
(Adult female; $n = 69$)		SE	—	0.303	1.472
		Variance inflation factor	—	1.034	1.034
		Partial R^2	—	0.687	0.054
3.3	.722	Parameter estimate	−11.066	5.028	−1.223
(Juvenile male; $n = 58$)		SE	—	0.422	2.009
		Variance inflation factor	—	1.015	1.015
		Partial R^2	—	0.719	0.002
3.4	.745	Parameter estimate	−5.444	3.968	−2.834
(Juvenile female; $n = 49$)		SE	—	0.348	1.844
		Variance inflation factor	—	1.109	1.109
		Partial R^2	—	0.720	0.013

TABLE 5. Coefficients of determination (R^2) and predictive error estimates from the validation ($n = 40$) of predictive equations to measured variables and Lipid Index for wintering Northern Pintails (*Anas acuta*) on the Southern High Plains of Texas, October–March 1984–86.

Equation	R^2	Mean prediction[a] error (± SE)	Lipid Index R^2
1.1 and 1.2 (fat)	.785	−9.921 ± 5.850[b] 6.16%	.662
1.3 (fat)	.765	−9.043 ± 5.853 6.24%	.659
2.1 and 2.2 (Condition Index)	.697	−0.0192 ± 0.0091 7.87%	.671
2.3 (Condition Index)	.700	−0.019 ± 0.0092 7.79%	.675
3.1–3.4 (log fat)	.733	−0.050 ± 0.0009 2.41%	.634

[a] Prediction error expressed as a percentage of the mean in the validation data set.

[b] Negative prediction error indicates overestimation of the true value

log DM, LMASS, LWING, and DSEX were significant ($P < .05$). Thus, CI was modeled with LTOTAL, LWING, LTARSAL, and LMASS for sexes separately and combined (Table 3). As in model 1, regression coefficient estimates were stable in equations 2.1 and 2.2; when sexes were combined, multicollinearity between TOTAL and DSEX resulted in relatively high VIFs for these variables.

Age and sex effects were significant when log fat was regressed on the same explanatory variables used in model 2. Furthermore, the structural variables LMASS and LWING were the only variables that contributed significantly ($P < .05$), but they were not homogeneous ($P < .05$) between age/sex groups. Therefore, four equations were estimated (Table 4). DAGE explained variation in log fat but not CI.

Given other model variables, body mass (MASS and LMASS) consistently accounted for the largest portion of variation in carcass fat (Table 2), CI (Table 3), and log fat (Table 4) of wintering Northern Pintails. Wing length (WING and LWING) explained 1–5% of the variation in carcass fat, log fat, and CI when other variables were already in the models. TARSAL did not contribute to any model. Variation accounted for by ninth and tenth primary lengths always differed by less than 1%. Consequently, ninth primary length was not tested in any model.

In the validation data set all models accounted for 69% or more of variation in carcass fat mass, CI, and log fat (Table 5). All models explained less than 70% of the variation in Lipid Index for validation data-set birds. Bias in all models was relatively low and negative. Predictive equations overestimated fat mass, CI, and log fat of validation data-set pintails.

DISCUSSION

A useful condition index will save funds by eliminating the need for expensive laboratory analyses and will lessen the need to sacrifice birds for direct nutrient analyses. The problems associated with using body mass alone as an index to condition of migratory birds have been noted (Bailey 1979, Wishart 1979, Iverson and Vohs 1982, Johnson et al. 1985). Because individuals vary in structural size, body mass will reflect that variability in muscle and bone, in addition to variation in lipids.

Models have been developed that predict fat content in waterfowl, but these require sacrifice and dissection of the bird (Woodall 1978, Chappell and Titman 1983, Thomas et al. 1983, Whyte and Bolen 1984). These equations may incorporate skin (subcutaneous), abdominal (omental), and/or intestinal (visceral) fat mass, and often account for most of the variation in total body-fat content. Our study was designed to develop models using explanatory variables that could be applied to live as well as dead pintails.

Miller (1989) developed regression models to predict carcass fat on live pintails from Sacramento Valley, California, but cautioned against their use outside that region. Our regression models for carcass fat provided better estimates of fat ($R^2 > .71$) for live pintails than those developed for California birds ($R^2 \leq .66$). However, similar to Miller's (1989) study, body mass alone accounted for most of the variation ($R^2 > .69$) in pintail carcass fat.

The possibility of a condition bias among waterfowl captured in baited traps versus the general population has been addressed (Weatherhead and Ankney 1984, 1985, Burnham and Nichols 1985). Hypothetically, birds in poor condition may be hungrier, less wary, and more likely to enter a trap containing food. Condition models could be used to test for evidence of a body-condition bias, given that samples of pintails captured both in baited traps and by presumably less-biased methods (e.g., net gun) are available.

Models could be used to test for annual variation in body condition and for changes in condition across the winter. Ringelman and Szymczak (1985) demonstrated the potential of condition indices in determining spatial differences in body condition and the preferability of condition indices to use of body mass alone. Hepp et al. (1986) also used condition indices to document a positive relationship between condition and survival in mallards.

These pintail condition models should be useful to waterfowl biologists. However, models should be verified when used outside the geographical range in which they were developed. For comparisons between age and sex classes we encourage use of model 3. Research also may require knowledge of absolute fat content. Importance of accuracy and precision will affect model selection. Care should be exercised to restrict model use to winter when changes in body mass primarily reflect fluctuations in fat, not fat-free dry mass (i.e., protein and mineral fractions).

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